Volume 41 July, 1955 Number 7

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Lubrication of Air Conditioning Machinery

TEXACO

REG. T. M.

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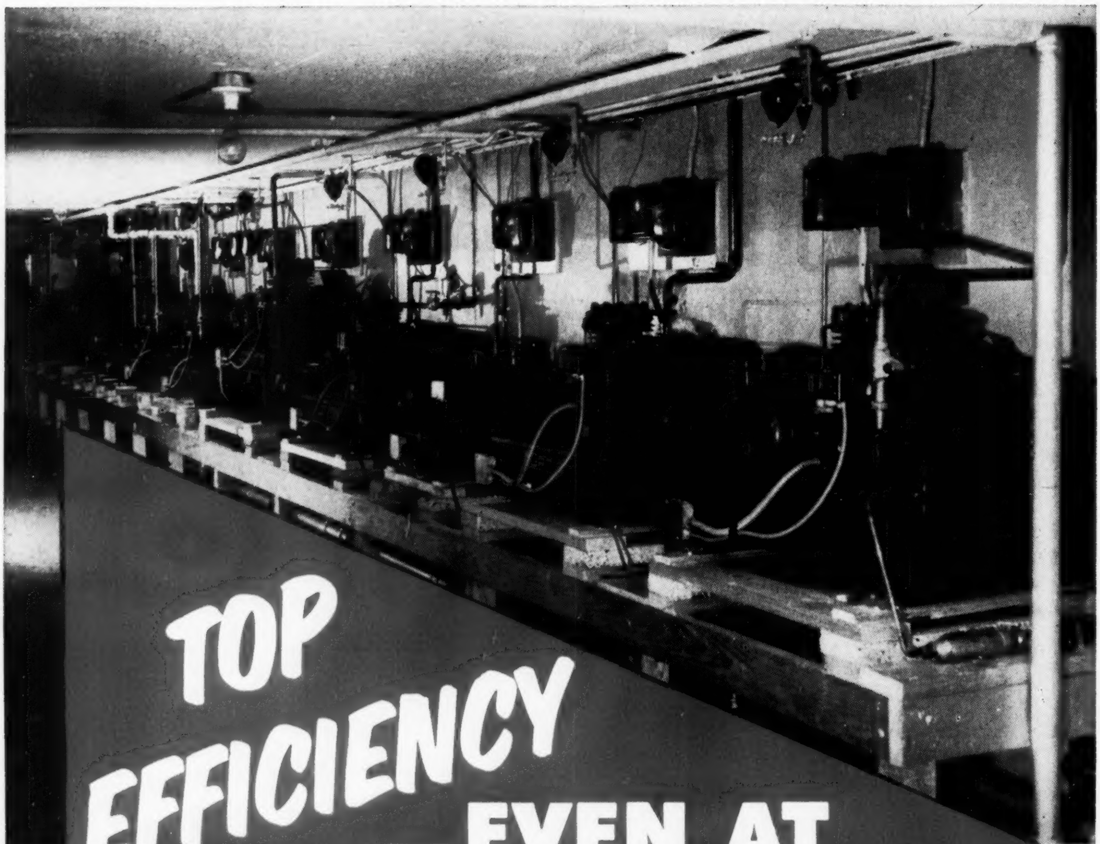

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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The Texas Company, 135 East 42nd Street, New York 17, N. Y.

Vol. XLI | July, 1955 | No. 7

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Lubrication of Air Conditioning Machinery

THE clothing of the body and the heating of living spaces in cold weather were at least well developed arts, if not strictly sciences, by 1873, when Lindé and others developed practical ammonia compression machines and cold expansion surfaces which could be used to cool enclosed spaces or materials and freeze liquids such as water. For fifty years or more, this development was used almost exclusively for refrigeration, that is, the cooling of materials or storage spaces to low temperatures. By 1925 or thereabouts, we had a civilization wherein people could keep themselves from freezing to death in wintry weather and could keep their food supplies reasonably fresh in controlled refrigerated storage spaces on a year-round basis. In the changeable fall and spring seasons and through the heat of summer, people were at the mercies of the weather, tempered only by the degree of clothing which they could conveniently add or modestly discard. Here and there, however, crude, bulky, inefficient and expensive installations were beginning to be invented and built by the pioneers of the air conditioning industry. These machines made attempts to even out the comfort during the variable heating season or to apply refrigeration principles to decrease temperatures during the season when the weather was too hot for comfort. From these beginnings, barely more than 30 years ago, has grown a modern science and industry of air conditioning, employing huge numbers of people in the development, manufacture, distribution, operation and maintenance of equipment, and contributing daily to the comfort of millions of persons.

Beyond the scope of comfort air conditioning, modern society has developed certain other needs for controlling the overall quality of air occupying a given space. These applications may be jointly spoken of as industrial air conditioning. Modern industrial operations involve detailed consideration not only of temperature but also of humidity, cleanliness and ventilation in relation to the nature of the material being made or stored.

The American Society of Refrigerating Engineers Air Conditioning-Refrigerating Data Book, Applications Volume (1955), lists the following main subdivisions of comfort air conditioning and industrial air conditioning:

Comfort Air Conditioning

Residences	Multi-Room Buildings
Small Stores	Passenger Ships
Eating and Amusement Establishments	Passenger Automobiles
	Busses
Variety Chain Stores	Airplanes
Theatres	Railroad Passenger Cars
Department Stores	

Industrial Air Conditioning

Processes and Storage	Printing Plants
Precision Manufacturing and Work Efficiency	Textile Fibers
	Libraries and Museums
Laboratories and Testing	Hospitals

While the term "air conditioner" is often loosely applied to a unit designed merely to cool a specified volume of air, it should be borne in mind that modern air conditioning involves bringing the air within a confined or semi-confined space to a desired condition (and usually maintaining that condition) with regard to the following air qualities:

Temperature — heating or cooling.

Humidity — addition or removal of moisture.

Circulation of air.

Ventilation — addition and exhaustion of air.

Removal of filterable material.

Purification from non-filterable material.

TEMPERATURE CONTROL

Since temperature is controlled in all except the most rudimentary systems, the air conditioning unit usually will contain either a heating unit or a cooling unit. The heating unit normally consists of an enclosed space in which to burn a fuel and a means to transfer the heat evolved to the air which it is desired to heat. The heat transfer may occur directly, as in a furnace, or a secondary fluid medium such as water or steam may be employed to transfer heat from the immediate vicinity of its evolution to a remote location. This latter procedure is sometimes more practical and economical than circulating the entire mass of air past the vicinity of the heat evolution. The number of moving parts in the heating unit which require lubrication is rather small. Certain types of burners have revolving parts requiring grease lubrication of their bearings at certain intervals; pumps for fuel or for transferring a secondary fluid medium, circulating or ventilating fans or shutters, or electric motors powering the various components will require oiling or greasing in accordance with the manufacturer's instructions. None of these services are ordinarily very severe, and general purpose lubricants will ordinarily suffice.

The cooling unit consists essentially of a compressor, condenser, evaporator, refrigerant, tubing and controls. The compressor acts to raise the pressure of refrigerant gas, simultaneously raising its temperature. The condenser is externally cooled by air or water and acts to cool or liquify the hot compressed refrigerant gas from the compressor. The cool liquid refrigerant is passed through a pressure reducing or expansion device to the evaporator where it tends to evaporate and expand as a gas. This process requires heat, which is picked up from the air or other fluid medium that surrounds the evaporator. This air or fluid medium is, of course, the material which is desired in the cold state, either cold air for use directly in air conditioning or a cold fluid medium such as water, which may be pumped to a remote location to cool air there in an additional heat exchanger. To complete the refrigeration cycle, low pressure, warm refrigerant gas is picked up from the evaporator by the compressor suction, compressed as before, and reused in the condenser and evaporator on new successive cycles.

OPERATION OF THE COMPRESSOR

The compressor functions somewhat as a pump, being designed to transfer the refrigerant gas from a vessel at comparatively low pressure to one at higher pressure. It is a precisely built machine having a number of internal parts and possibly some external parts that require lubrication. These parts place a rather severe duty on lubricants because of close fits, temperatures caused by compression, and the presence of various metals, refrigerants, and often electrical components in contact with the oil. Specialized characteristics are required to meet this duty, and these characteristics are supplied by preparing special lubricating oil products for refrigeration and air conditioning compressor service.

Reciprocating Type

The reciprocating type of compressor resembles the automotive engine in principle and design, but from one or two up to six, seven or more cylinders may be used in a single machine. Design is not restricted to "in-line" or "V" arrangement as in automobile engines, but may comprise "V", "Y" or radial arrangements of the cylinders as desired by the designer. The pistons are fitted into the cylinders with suitable connecting rods, wrist pins, and crankshaft connections. The compressor is dependent upon an outside driving mechanism to which it may be directly or belt connected. The driving mechanism is commonly an electric motor, however reciprocating steam engines or steam turbines are also used.

A large number of refrigeration compressors, particularly the smaller units of fractional and one to three horsepower sizes, do not use piston rings. Instead, the designers plan for close clearances between the pistons and the cylinder walls, and depend upon the lubricating film to maintain the necessary seal. Other designs follow automotive practice of providing compression and/or oil-scraper rings. Another marked difference pertinent to the reciprocal refrigeration compressor is the manner in which the gas to be compressed may be drawn into the cylinders. In contrast to taking the gas charge into the top of the cylinder as is customary in the automotive engine or air compressor, the refrigeration compressor may draw in the low pressure gaseous refrigerant through the crankcase, using valve mechanisms which are located adjacent to or a part of the piston.

Rotary Type

The rotary positive displacement type compressor brings about compression through the rotation of an eccentrically driven roller which moves in a gyratory manner in a closed cylinder. The inlet and discharge passages are separated by one or more blades held in contact with the roller surface by springs or oil pressure. Oil also serves to maintain the necessary seal between the surfaces of the roller and housing. Submersion of all the moving parts in oil under pressure protects them adequately against wear and permits manufacture to very close clearances. While widely used in household refrigerators, the rotary type compressor is probably only used in fractional horsepower air conditioning units. For larger loads, the reciprocating type compressor described above or centrifugal compressor described below is usually favored.

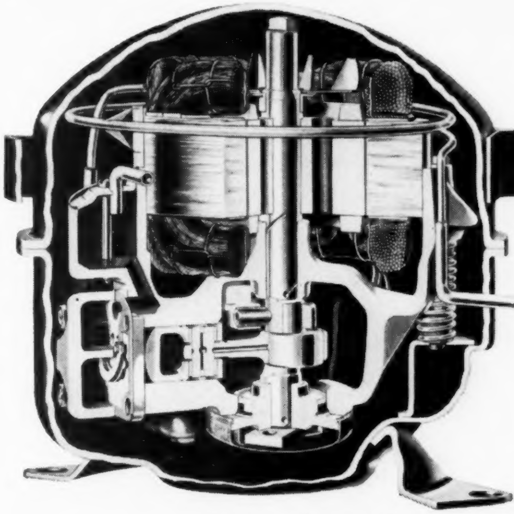
Centrifugal Type

The centrifugal type compressor resembles a centrifugal pump in design and construction. A rapidly rotating impeller with curved vanes picks up the low pressure gas, rotates it, and discharges it outward by centrifugal action, resulting in increased pressure. By successively channeling the gas through several impellers or stages, increasing pressure up to the limits of the mechanical design and strength of materials can be achieved. High volume of refrigerant can be handled at high and very even pressures. The machine is free of vibrations and has none of the wear and operating problems attributable to valves, pistons, rings and cylinder walls in reciprocating machines. The centrifugal compressor is thus particularly suited to heavy duty, continuous, large horsepower operations.

Hermetic Units

While original designs for refrigeration were generally for separately assembled, open type compressors, belt or shaft driven by a separate motor, the recent trend in "small" compressor sizes below 5 HP motor capacity has been toward the sealed or hermetic unit. In these, the electric motor is built into the same casing as the compressor, and the electric motor driving section and the refrigerant compressing section, whether reciprocating or rotary type, are mounted at opposite ends of a single shaft. Both sections are exposed to the refrigerant vapors and heat of compression and are lubricated from the same oil reservoir.

Hermetic units are usually factory-assembled and sealed, and extreme precautions are taken to exclude all foreign materials such as moisture, air, and dirt. The units may be "sealed" by brazing or welding together the parts of the case or "accessible" through bolted, flanged and possibly gasketed components. The sealed type are ordinarily



Courtesy of Tecumseh Products Company

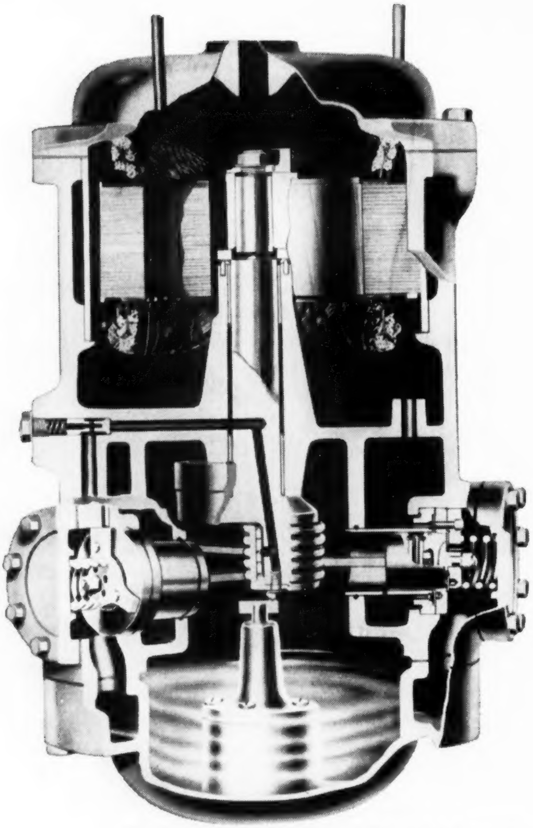
Figure 1 — ⅓ HP single cylinder hermetic unit for "Freon-12 or 22". Oil level is held at mid-point of cylinder and connecting rod. Centrifugal force in channels in the crankshaft delivers oil to bearings, wrist pin and cylinder walls.

returned to factory service departments for any repairs necessary, whereas the accessible type can undergo certain repairs or replacement of parts in the field, providing all due precautions are taken to exclude air, moisture, etc., as in the original construction of the unit. Units of upward of 5 HP capacity usually are separately driven, however the hermetic design is finding occasional application in the intermediate range of 7.5-20 horsepower.

LUBRICATION PRACTICE

Splash, flooded, and forced feed lubrication systems are used in air conditioning compressors. The splash and flooded systems are more adapted to the vertical reciprocating and rotary compressors, whereas the forced feed system is more universally applicable, including horizontal reciprocating and centrifugal compressors. The system used for lubrication of compressor parts will have a decided influence on the grade of oil that should be used. It will, therefore, be of interest to note the principles involved in these systems.

Splash lubrication provides distribution of the oil at each revolution of the crank, the level in the crankcase being maintained just high enough to permit the crank to dip in and splash the necessary amount of oil to the cylinder walls and bearings. Continued operation will form a fog of lubricating oil above the main body of oil in the crankcase which will insure adequate lubrication of main, wrist pin, and crank pin bearings, provided these bearings have ample clearance to permit entrance of the oil. The splashing of the dippers and the



Courtesy of Airtemp Division, Chrysler Corporation

Figure 2 — 5 through 15 HP sealed radial compressor. Oil pump delivers oil past the pressure relief valve to the main and connecting rod bearings. The oil pump is reversible so that direction of rotation is not a problem.

larger bearing clearances may cause a somewhat higher noise level than is desirable in air conditioning installations. The splashing action may also cause oil frothing and carryover into the compressed refrigerant system. Proper design and choice of lubricating oil can minimize these objectionable features.

Flooded lubrication provides arrangements of vanes, discs, screws, shaft grooves, etc. that raise the oil from the sump to an elevated point from which it gravitates back down to the various parts. At most, only a very mild pressure is provided by these devices, but the oil is less violently agitated than in the splash system and is perhaps a little more positively transferred to the point where it is required. Some quieter operation and less fogging and oil carryover should therefore be possible with the flooded lubrication system.

Forced feed lubrication provides gear, vane or plunger pumps and tubing or cast or bored channels to carry the exact quantity of oil required to the various parts. The moving stream of oil can be utilized not only to lubricate but to carry heat away from the parts, coolers sometimes being included at some point in the oil system. All moving parts can be more closely and accurately fitted to provide a smoother running, quieter machine. Forced feed lubrication is rather generally supplied in units of one horsepower and above, and is almost universal in units above 15 HP size.

On many types of the larger machines, internal and external parts are lubricated individually. The design may provide both a mechanical forced feed lubricator with several outlets for cylinder, stuffing box, and internal bearings and an independent gravity or mechanical pressure circulating system for all external bearings.

Forced feed lubrication permits effective filtration or purification of the oil while it is circulating. Even the smallest machines include a fine wire mesh screen over the pump suction to strain out such stray particles of metal or trash as might be present. Larger machines may circulate all or a portion of their oil through a filter designed also to remove some of the sludges or contaminants which might be present.

EFFECTS OF REFRIGERANTS ON LUBRICATING OIL

The choice of a refrigerant will be influenced by the specific conditions to be met by an air conditioning system; and the refrigerant, once chosen, will influence the design of the compressor and the characteristics required in the lubricating oil. In applications where the reciprocating compressor is most advantageous, refrigerants of high vapor pressure give best results, due to low piston displacement and small friction loss. With the centrifugal compressor, it is necessary that the refrigerant have low vapor pressure to reduce the number of stages. A heavy density of the vapor is desirable, however, in order to reduce the peripheral speed.

"Freon-12" or "Genetron 12", "Freon-22" or "Genetron-141", and "Freon-114" are the refrigerants most commonly used in the hermetic units so widely favored for small air conditioning units. A special refrigerant "Carrene-7" is occasionally used to compensate for the capacity reduction caused by the reduction in speed occasioned when a 60 cycle motor is connected to a 50 cycle power source. Large scale air conditioning units employ a wide variety of refrigerants including various "Carrene", "Freon" and "Genetron" compounds, ammonia and sulfur dioxide. These last two are most apt to be used in installations where the primary cooling system is remote from the space cooled, e.g. where water is cooled and circulated to space coolers throughout a building. The danger

of escaping irritant gases to occupants of the building is thus minimized.

These usual refrigerants have varying degrees of miscibility with lubricating oil ranging from practically zero for ammonia to complete miscibility for methylene chloride, "Freon-11", "Genetron-11", "Freon-12", and "Genetron-12". Refrigerants "Freon-22", "Genetron-141" and "Freon-114" present a special case. They will generally be completely miscible with lubricating oils at temperatures above a certain "miscibility temperature", but their solution with oil may separate into two liquid phases when cooled below that temperature, depending on the composition of the mixture. A principal effect of refrigerant dissolved in the lubricating oil is a reduction in viscosity which may reduce the ability of the oil to do its job of lubricating the machine and sealing in the refrigerant pressure.

The design of the compressor will determine the extent to which properties of the lubricant are affected by properties of the refrigerant. The centrifugal machine presents a comparatively simple problem in that there is little contact between refrigerant and lubricating oil. The leakage of the refrigerant will not be sufficiently extensive to give any concern as to the resultant lubricating ability of an oil which has been specifically refined for this class of service. In reciprocating and rotary machines, splash and flooded lubrication where the refrigerant circulates through the crankcase immediately establishes an equilibrium between oil and refrigerant, as will any type of lubrication in the sealed hermetic compressor. Machines with forced feed lubrication will vary in the degree of contact afforded between oil and refrigerant.

Apart from mechanical and constructional conditions, the amount of "Freon" or "Genetron" refrigerant which will be absorbed by any mineral oil will be dependent upon the viscosity of the oil, the temperature and pressure of contact, and the nature of the oil. Lower viscosity oils absorb more of these types of refrigerant for a given weight than will higher viscosity oils. Low temperature and high pressure favor absorption. A paraffinic oil absorbs slightly less of these types of refrigerant than a naphthenic oil of equal viscosity.

The figure opposite indicates the magnitude of the effect of refrigerant ("Freon-22") in solution in a series of napthene base refrigeration grade lubricating oils at 100°F. The oils range in nominal viscosity from 150 to 300 Saybolt Universal Seconds at 100°F.; and equilibrium mixture pressures of 0-115 p.s.i.a. are covered. A comparative curve for a nominal 300 SUS viscosity paraffin base oil is also shown. Data curves of this type may be used in estimating the viscosity of mixtures in the crankcase of a reciprocating or rotary compressor whose design affords intimate contact of the circulating refrigerant and the lubricating oil. The positions of the various curves will, of course, be different for different refrigerants, different oils, and different temperatures.

OIL CARRYOVER

If a compressor crankcase contains too much oil or agitation is too violent, excessive quantities of oil may be carried to the cylinder walls. Part of this excess may tend to work its way past the piston or piston rings and enter the compressed refrigerant spaces where it will interfere with condenser and evaporator efficiencies. Some quantities of oil may be carried along in the refrigerant stream as it passes from crankcase pressure to discharge pressure in the compressor.

Many refrigeration system designs include an oil separator to minimize the carryover of oil, and the separated oil may be returned to the compressor for reuse. The actual function of the oil separator is to remove any particles of oil from the refrigerant while it is in gaseous form, after it has left the compressor. The larger the oil particles, of course, the more effective will be the separator. It should, therefore, be located at sufficient distance away from the compressor to permit adequate precipitation of the oil from the refrigerant gas. The capacity or volume should be ample so that velocity of the gas passing through the separator will not be too high. Where it is impossible to locate the main oil separator elsewhere than adjacent to the compressor, it is well to use an oil of as low an atomizing tendency as possible, i.e. one of as high viscosity as is suitable for the lubrication requirements of the machine.

LUBRICATING OIL REQUIREMENTS

Type of Oil

Lubricating oils commonly used in air conditioning compressors today are stable, well refined light

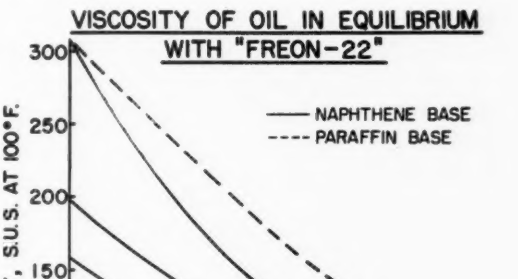
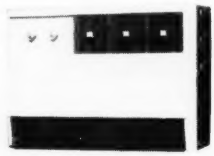


Figure 3

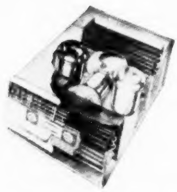
COMFORT AIR CONDITIONERS

Rooms

Courtesy of Carrier Corp.



Courtesy of Philco Corp.

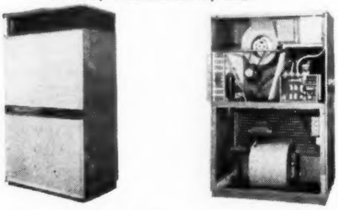


Courtesy of Frigidaire Division, General Motors Corp.

Homes

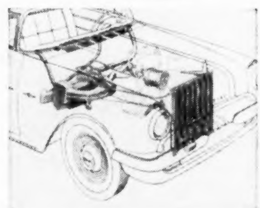
Courtesy of Airtemp Division, Chrysler Corp.

Office, Restaurants, Etc.



Courtesy of General Electric Co.

Automobiles



Courtesy of Pontiac Div., General Motors Corp.

Figure 4

colored or "pale oils". In the past, these oils were rather generally prepared from naphthenic base crudes, in order to utilize their inherent low pour points and freedom from wax. Such oils have a long history of satisfactory service in refrigeration and air conditioning units of widely varied design. As refining techniques and refrigeration designs progressed, it became feasible and in certain instances desirable to utilize pale oils prepared from paraffin base crudes. Today both types of lubricants are available to the manufacturers of air conditioning equipment, and the choice between them is based on experience and exhaustive performance tests in equipment it is intended to market. Mechanical designs are usually being developed several years ahead of the time at which the final machine is marketed. A series of "life tests" on combinations of components, including various types, brands and viscosities of lubricating oils, can therefore be run under normal or overloaded conditions for periods up to two years. The units under test will be checked at regular intervals for efficiency of operation, and will be completely disassembled at the end of the test for thorough examination of all components. The performance of the lubricating oil will be rated by its changes in physical characteristics and by observations of wax, gum, varnish, sludge, wear, corrosion and copper plating within the system.

Viscosity

During the eighty years of mechanical refrigeration experience and thirty years of air conditioning experience, certain principles of proper lubrication have been established just as established features and principles of mechanical refrigeration were developed. With regard to viscosity, it was recognized that the lubricating oil must be fluid or thin enough to move readily from a sump or reservoir to the point at which its lubricating effect is desired. At that point it must be viscous or thick enough to hold the two metal surfaces apart and, in many instances, to hold in the pressure of the compressed refrigerant gas. Generally speaking, the oil chosen should have the lowest viscosity which will give the required sealing-in of the refrigerant used over the range of temperatures, pressures and refrigerant dilutions anticipated. To facilitate the design engineer's consideration and choice, a number of lubricant suppliers make their refrigeration quality lubricating oil available in nominal viscosities of 80, 100, 150, 200, 300 and

500 Saybolt Universal Seconds at 100°F., thus completely bracketing the range which might normally be required.

Viscosity Index

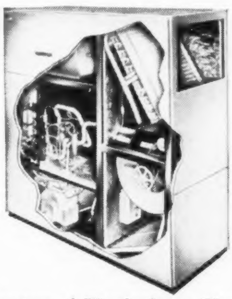
Aside from the nominal viscosity of a lubricating oil at a specified temperature such as 100°F., the tendency of the oil to reduce viscosity with increasing temperature often bears consideration. This tendency is measured on an arbitrary scale known as "Viscosity Index", in which oils whose viscosities change rapidly with temperature are assigned low V.I. numbers and those whose viscosities change slowly are assigned high V.I. numbers. This feature becomes of importance if an oil is to function at several different, widely separated temperatures, which is not ordinarily true of air conditioning compressor equipment. In the range of Viscosity Indices encountered on commercially available refrigeration compressor oils, viz. 25-100 V.I., an oil properly chosen for its viscosity under the normal operating conditions of temperature and refrigerant dilution will not ordinarily either thin to a dangerous degree in a slightly overheated bearing or thicken to a point where it will not be properly delivered to the point of requirement in a cold compressor. While high V.I. may appear desirable to even out the viscosity differences at various points, this effect must be balanced against the possible detriments of the higher pour test and wax content usually associated with high V.I. oils. These features are discussed further below.

Volatility

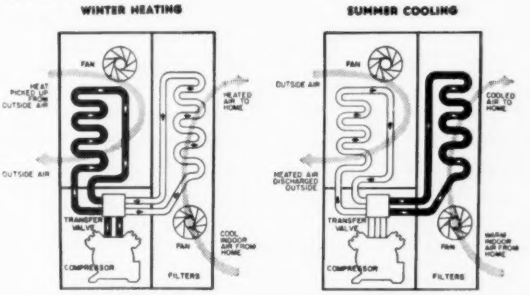
While the average air conditioning compressor will function at maximum temperatures considerably below 200°F., there may be installations of the booster type which exceed 300°F. on the refrigerant discharge side of the compressor. Under high temperature conditions, the relative vaporizing tendencies of petroleum lubricating oils must be considered. The oil used must not vaporize excessively at the temperatures and pressures involved, lest it carry over too rapidly, overload and pass through the separator, and give objectionable accumulations in the cold side. The desired quality is imparted to refrigeration grade compressor lubricants by use of due precautions in their manufacture to assure that materials are not included which would be volatile at the temperatures to be encountered. This quality has additional significance in the modern vacuum dehydration step applied to

COMFORT AIR CONDITIONING

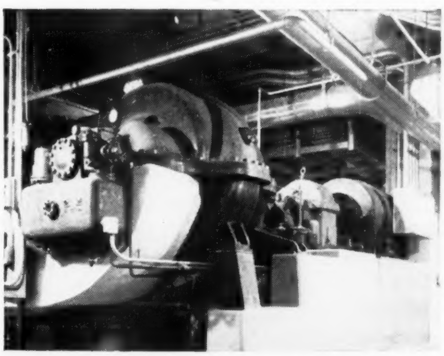
Heat Pump for Homes



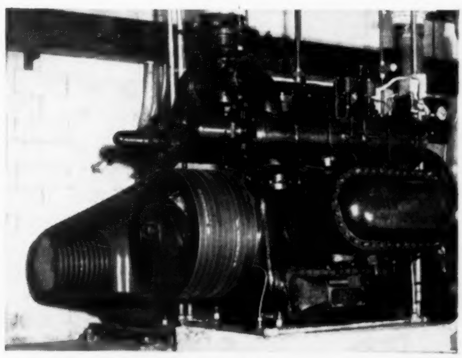
Courtesy of Westinghouse Electric Corp.



Buildings



Courtesy of Worthington Corp.



Courtesy of Frick Company

Figure 5

many hermetic units during their manufacture. The units often contain a portion or all of their lubricant charge at the time the vacuum and heat are applied for dehydrating purposes, and any volatilization of the lubricant may both interfere with the drying operation and put undue load on the vacuum pump. A common pressure for vacuum dehydration is 100 microns absolute pressure, at which the commercially available refrigeration oils will not vaporize appreciably below 200°F.

Foaming

Foaming of the lubricating oil in the crankcase may occur, particularly in reciprocating units where the refrigerant vapors at suction pressure enter the compressor through the crankcase. The degree of foaming can be controlled to a certain extent by the manufacturer of the lubricant, through his oil refining process or the inclusion of anti-foam agents which impart a foam killing effect when present in the "trace" amounts of only a few parts per million. A high degree of foaming is generally considered objectionable, since it will contribute to oil carryover past the piston or piston rings and may interfere with pump action in a forced feed lubrication system. Some designers of refrigeration compressors consider a moderate amount of foaming beneficial in that it may contribute to the effectiveness of splash lubrication or muffle some of the noise of moving parts. Design of the compressor will thus affect the degree of oil foaming which can be tolerated or is desired.

Pour and Wax

Simple fluids such as water, alcohol and glycerine have fixed and accurately reproducible freezing points at which a complete change from the liquid to the solid phase takes place. Lubricating oils, however, are complex mixtures of hydrocarbons of various freezing points, which behave like solutions and frequently deposit some portion of their constituents before the whole mixture becomes solidified. Wax is particularly susceptible to such deposition, but all hydrocarbons tend to thicken as temperature is reduced and will eventually become solids. These effects contribute to the increasing viscosity of lubricating oil as its temperature is reduced, and eventually the oil ceases to flow at all, due to the restriction imposed either by separated solid materials or extreme viscosity of the liquids present. Lubricating oils from paraffin and mixed base crudes tend to cease flow due to the interlocking network of wax crystals that form as temperature is reduced; oils from relatively wax free naphthene base crudes generally cease to flow due to the viscosity thickening action.

The pour test is the measure of the lowest temperature at which a petroleum oil will pour or flow when it is chilled, without disturbance, under definitely prescribed conditions. The proviso in regard to disturbance is especially important. Extensive research has indicated that any agitation or stirring of the oil while cooling causes it to solidify at a lower temperature than when held absolutely motionless. This is explained by the assumption that movement of the oil disturbs the fine network which is forming. When undisturbed, these microscopic paraffin wax particles grow and interlock more easily into a formation that supports itself and facilitates solidification. The pour test procedure should, therefore provide for absolutely motionless cooling during the time involved.

In lubrication of compressors which may be exposed to low temperatures at start-up, pour characteristics can affect the initial selection of lubricating oils. These must have pour tests below the lowest expected start-up temperature to enable handling by the conventional types of oil circulating systems. The oil must also remain comparatively fluid at the lowest temperatures to which it may be subjected during the operation. These temperatures will be encountered in the expansion or refrigerating side of the system, after the refrigerant has passed the expansion valve or capillary tube. If the refrigerant is carrying a high percentage of oil at this point, any wax congealment might lead to faulty operation of the expansion device or restricted heat transfer through the coated evaporator surfaces.

Refrigerant "Floc" Test

Refrigerant dissolved in the lubricating oil will have the effect of reducing the pour point, thus widening the temperature range at which the oil may be used without difficulties from complete congealment. However, the presence of dissolved refrigerant will not necessarily completely prevent the separation of waxy components, particularly at the coldest points in the system where the proportion of refrigerant is high but the refrigerant is evaporating rapidly and increasing in concentration of oil. A Wax Precipitation Test is therefore used to measure tendency to precipitate wax from the solution of oil in refrigerant.

The test is usually made on a 10% mixture of oil in "Freon-12", but it could be made on whatever percentage concentration and oil-soluble refrigerant the refrigeration or air conditioning system is designed to use. The temperature of the refrigerant-oil mixture is gradually reduced until a first faint wax haze is observed. This is recorded as the Wax Haze Temperature. The temperature of the mixture then is further reduced until the tiny wax crystals forming the haze gather together into observable flocs. This temperature is recorded as the Floc Point. The tiny haze-forming crystals

are not considered harmful; and it is not until the crystals begin to flocculate into clumps that undesirable waxy deposits and clogging can occur in the refrigerant system. This floccing feature is probably of less importance in air-conditioning installations than in low temperature refrigeration systems, but the design of the individual installation will indicate the degree of consideration which must be given to the pour and floc characteristics of the compressor lubricating oil.

It should be pointed out that the amount of oil circulated with the refrigerant in a well designed and operating air conditioning system will usually not exceed 1 or 2% of the refrigerant circulated. An oil circulation as high as 10% should be exceedingly rare. Running the Wax Precipitation Test on a 10% mixture of oil in refrigerant thus provides a good margin of safety for translating test results to the anticipated operation of the unit.

Moisture

Moisture in refrigeration and air conditioning systems freezes to ice at whatever point it first reaches a temperature below 32°F., causing stoppage of the expansion control device, plugging of refrigerant tubing, or reduced evaporative efficiency in the cooling coils. The system as a whole represents a rather complex mixture of materials, hydrocarbons, refrigerant, metals, packing and sealing materials, electrical insulation, which under the impetus of intimate contact and temperature enter into chemical reactions with each other. Any moisture present will make the reactions easier and more numerous, giving corrosion which may damage any number of the parts of the system and render it inoperative.

It is therefore common practice for refrigeration equipment to be thoroughly freed of moisture, before being placed in operation, by application of vacuum or heat, or both, or the equipment may be thoroughly flushed out with dry refrigerant gas. The manufacturers of lubricating oils and refrigerants contribute their share to the dryness of the equipment by manufacturing their products to extremely low limits of moisture content. Oils are commonly prepared to contain less than 20 parts per million of water, and refrigerants less than 5 parts per million. The products often are packaged in small sealed packages to preserve their moisture-free qualities until the exact time of use.

The Dielectric Strength Test based on resistance offered to passage of electric current has been devised to assure that refrigeration grade lubricating oils are satisfactorily free of moisture. The procedure involves subjecting the oil to high voltage in a standardized test cup fitted with fixed gap electrodes of copper or brass. Resistance of oils

Courtesy of Frigidaire Division, General Motors Corporation

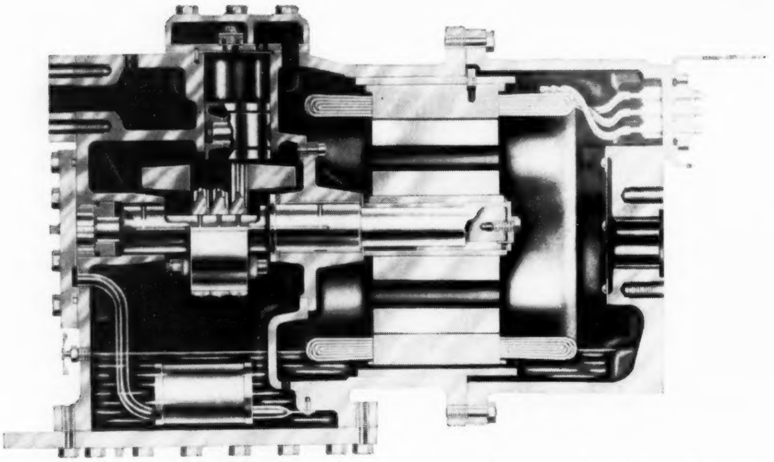
Figure 6 — Meter-Miser rotary compressor, hermetically sealed and permanently lubricated. Used in pairs in ¾ and 1 HP room conditioners, singly in ⅓ and ½ HP units.

to a stress of at least 25,000 volts per millimeter was found to be an indication that they were sufficiently dry for refrigeration purposes. The satisfactory maintenance of the 25,000 volt electrical potential simultaneously assures the absence of solid impurities which would also be objectionable in the lubricant.

Stability

Refrigeration grade compressor oils are expected to give years of service, and this can be achieved only if they are manufactured to be extremely stable toward heat and the materials with which they come in contact. The required stability is imparted by very careful selection of the crude sources utilized, the fraction of crude selected, and the refining processes applied during manufacture. Additional stability may be imparted by including additives, but this practice is not yet widespread in refrigeration usage.

Due to increases in compression capacity, limited space and limited cooling water, the average operating temperature of air conditioning compressors has steadily risen. Higher operating temperatures tend all the more to break down lubricating oils and may lead to formation of varnish and



Courtesy of Worthington Corporation

Figure 7 — Cross section of a semi-hermetic compressor used in commercial packaged units and residential units. A rotary vane type pump on end of crankshaft delivers filtered oil from the sump to various parts shown.

gum films. The chemical reactions occurring are complex and not fully known, even though considerable research on them has been conducted. They are not simply oxidation of portions of the oil, inasmuch as oxygen and oxidizing conditions are rather completely excluded from the systems. It is likely, rather, that chain reactions of various oil and refrigerant components occur and are catalyzed or entered into by the moisture, metal surfaces, metallic wear particles, sealing compounds, etc. that are present. In sealed hermetic units, the reactions may be compounded further by the electrical components present or by stray electrical currents.

One particularly disturbing series of reactions encountered in various types of machines tends to dissolve copper parts and plate the metal out on other metal surfaces, such as bearings, where change in the nature and thicknesses of surfaces can quickly lead to damaging wear. This "copper plating" phenomenon has been given much study without resulting in a complete explanation or solution. It has been found, however, that a completely dry system largely eliminates copper plating difficulties. This is an additional reason for providing extremely dry lubricants and refrigerants.

CARE IN HANDLING LUBRICATING OILS

Petroleum oils which have been actively dehydrated will tend to re-absorb a certain amount of moisture when exposed to the air for any length of time. They should, therefore, be carefully stored and the containers opened only when it is necessary to use the oil. If any oil remains unused, the containers should be sealed as tightly as possible. Before usage, it is advisable to keep containers at room temperature for at least 24 hours. This will equalize temperature and reduce the possibility of moisture condensation in the oil. Where oil is handled in bulk quantities, as at the plants manufacturing air conditioning equipment, facilities are usually provided to vacuum dehydrate and blotter press the oil just before use to assure that it is properly moisture-free and trash-free.

AUXILIARY EQUIPMENT

As in the heating unit, the cooling unit may include pumps for transferring a secondary fluid medium, circulating or ventilating fans or shutters, and external electric motors, all requiring oiling or greasing with general purpose lubricants in accordance with their manufacturers' recommendations. Some large units may be powered by steam pumps or turbines, requiring the proper grade of steam cylinder or turbine oil. Features of the auxiliary equipment which may be utilized to control humidity, circulation, ventilation and air purity in the overall comfort air conditioner are described below.

Humidity Control

Most of the comfort air conditioning installations for rooms, residences, and such relatively small enclosed spaces merely remove a portion of the moisture present in the air when on cooling cycle or evaporate a portion of water from an open reservoir into the air when on heating cycle. This tends to give a variable humidity whose numerical value is a function of the temperature of the air inside the air conditioning unit, the proportion of total air circulated, and the temperature the conditioned air assumes upon its return to the enclosed space. On larger units, or in industrial air condi-

tioning applications where humidity is of prime importance, humidities of selected magnitudes within a reasonable range may be provided by suitable controls. One such system on cooling cycle uses a combination of temperature and humidity controllers, i.e., a thermostat and a humidistat. During periods of proper humidity, the thermostat operates to modulate the flow of cooling water to a coil over which the circulating air passes. When humidity rises too high, the humidistat acts to override the modulation feature of the thermostat, causing the control valve to work only in a two-position, "on-off" manner. Maximum cooling and dehumidification therefore occurs during the cooling period, but the temperature controller can still prevent the temperature in the enclosed space from falling too low. Many other combinations of cooling, circulating, and ventilating for humidity control are possible, and related methods for introducing controlled heated and humidified air have also been devised.

An application of special interest is becoming reasonably wide-spread in newer houses or stores, which are more tightly constructed and may not permit the degree of air leakage for ventilation that was previously prevalent. These buildings may become overly moist during the winter or in their cool, dark cellars in summer. Mechanical dehumidifiers, comprising a complete small refrigeration unit may be set up in such spaces. The cold evaporator is used to condense water from the circulated air, delivering the condensate to a drain. The condenser is air cooled and acts to heat the air in the space. Both actions tend to dry the air and eliminate undesirable condensation on cool surfaces or the prevalence of mildew in storage spaces.

Circulation and Ventilation

Practical considerations of heat exchange and air movement preclude moving all the air in an enclosed space past the heat transfer surface in an extremely short space of time, so that the temperature of the air coming from the heat transfer zone is exactly the temperature desired in the enclosed space. Only a portion of the air is therefore circulated; and it is overheated or under cooled (sometimes also overhumidified or overdehumidified) in passage, and then subsequently mixed into the bulk of air in the enclosed space to give the desired temperature, humidity, etc. Proper distribution of the moving air is of extreme importance inasmuch as drafts or excessive noise can render completely uncomfortable a system that is otherwise properly designed.

Proper air distribution is a subject far too large for the scope of this article. There are many text and reference books covering the various principles and application, and new developments are constantly being covered in the trade literature. For a very general and limited summary, it may be stated that small air conditioning units generally have integral fans and grill work designed to pick up and discharge the air with a maximum of space coverage and minimum of direct drafts that can hit personnel. Larger systems utilize duct work that is carefully designed for the space and the load imparted both by personnel and external weather. General limits for proportion of air circulated and air velocity under various circumstances have been established. Cost and appearance must be considered. Past experience is a large factor in designing an installation that will be comfortable with respect to air circulation.

Aside from the above features of circulation, the air conditioning system must usually provide for ventilation of the enclosed space, i.e., exhaust of stale air which may contain odors, fumes, and smoke and introduction of fresh air to replace the stale. The general principles utilized include maintaining a small positive pressure on the conditioned space, sizing intake fans and duct work to introduce 100% outside air when conditions make it feasible, and conditioning intake air as it is introduced. Many other features must be considered as the design of a particular installation progresses.

Purification

The circulation of all the air in an enclosed space past a given point affords an excellent opportunity to free the air of dust, fumes, odors, pollens, or bacteria at that point. The purification devices used range from simple filters for solid materials to complex washing and sterilizing systems. The general types available include centrifugal collectors, dry filters, coated filters, electrostatic precipitators, adsorption equipment, and spray or scrubber washers.

Filter systems are by far most prevalent. Their design provides contact of air with a filter material such as metal wool, glass fibers or glass wool without undue restriction to air flow. Filter elements may be either cleanable or disposable, but some provision must be made for removal of the accumulated material. The filter material may be treated with a viscous liquid to increase its ability to pick up material from the air, and petroleum oils are often used for this purpose. The filter is often built as a continuous strip or belt that rotates successively through the air stream, an oil bath for cleansing and recoating purposes, and a draining section. A recent development has been a special petroleum base filter coating material that is applied to filters by a hot dipping process. When the filter cools, the coating material congeals to present a large surface of a tacky nature that obviates messy dripping from the filter after it is placed back into service.

APPLICATIONS

The foregoing discussion has been chiefly concerned with the application of compression type refrigeration to air-conditioning. There have been parallel advances in the manufacture of furnaces and in adsorption and steam jet refrigeration systems. The lubrication requirements in all of these are rather limited and are therefore not covered in this article. Likewise such important adjuncts of air conditioning design as insulation and moisture-proofing, load calculations, piping and ductwork, cooling towers, electrical and control systems, weather studies, and building design bear little or no relation to lubrication and have not been covered here.

In closing it may be of interest to summarize briefly some of the particular features of the main subdivisions of comfort and industrial air conditioning that were listed on page 73.

In residences, small stores, eating and amusement establishments the loads are small, variable mainly with the weather, and price is usually an important feature both in the initial installation and in the operation and maintenance. Units are therefore kept simple and usually operate under "on and off" conditions to a thermostat control only. The operator adjusts the temperature setting to a comfortable figure, perhaps has manual controls of circulation and ventilation, but accepts the humidity, purification and operating cycle built into his machine. Noise level may be major factor in that the air conditioning unit will be rather close to the people inhabiting the space.

Residential comfort air conditioning is expected to grow from about 25,000 units in the U. S. in 1950 to 2,000,000 or more in 1960, which will still represent less than 10% of the existent centrally heated residences. The percentage of air-conditioned commercial establishments may logically be expected to be higher, since the competitive angle of attracting or maintaining business enters in.

Larger eating and amusement establishments, variety chain stores and theatres involve larger numbers of people and greater loads, but space arrangements will usually permit a unit of relatively simple design to provide the desired degree of comfort. Special consideration may need to be given to local areas, e.g. areas where cooking is done, entrances, smoking areas, etc. Air conditioning may be accomplished by a number of package units in various locations, each individually controlled as to operating temperature, or a central unit may be installed. In the latter instance, choice may be made as to circulating the air through ducts to or from the unit or circulating an intermediate fluid, either heated or cooled, to individual heat exchangers scattered through the building. Either system can be used for temperature control; but circulation of at least a portion of the air will usually be required if humidity control or purification is desired.

Department stores and multi-room buildings represent the heaviest and most complex loads for air conditioning. In these applications, the whole gamut of designs of machinery and controls will be encountered. A central unit is inevitably required, and careful consideration must be given to the various zones within the building that have different requirements. In large buildings, an inner zone, well insulated by distance and materials from the effect of outside weather, may be encountered which will actually require cooling at times when the perimeter of the building is being heated. Obviously great flexibility both of total output and individual operating sections is required. Units of this size and complexity will be large and expensive to install and will generally require a supervising engineer and an operating force around the clock to keep them operating and properly serviced.

Passenger ships will be similar to department stores and multi-room buildings in their air-conditioning requirements and means of satisfying them. Special requirements exist in the lines of maintaining proper operation during the normal roll and pitch of the ship, exposure to the corrosion of sea air and sea water, and reliability during extended voyages. Passenger vehicles present the problems common to residence and small stores except that a smaller space is concerned and insulation from weather conditions is poorer due to metal construction and large proportion of window and door area. Power for the air conditioning unit is usually drawn from the driving engine of the vehicle and is thus subject to variations in speed that affect the air conditioning design.

Industrial air conditioning presents problems peculiar to the individual installation. While the installation is made primarily for the benefit of the operation being conducted, if personnel are to work in the air conditioned space, some consideration must also be given to their comfort and working conditions.

In the foregoing pages it has only been possible to touch very lightly on the many aspects of the modern science and industry of air conditioning. The important part that specialized lubricating oils play in the extended, trouble-free operation of refrigeration compressors has been pointed out and attention was directed to the quality petroleum lubricants and greases that are available for other operating equipment. For those desiring more detailed information, attention is directed to various reference books and publications.

Printed in U. S. A. by
Salley & Collins, Inc.
305 East 45th Street
New York 17, N. Y.